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THE PREPARATION OF A CATALOGUE OF ATMOSPHERIC TEMPERATURE AND WIND PROFILES FROM ROCKET-SONDE TEMPERATURE SOUNDINGS

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THE PREPARATION OF A CATALOGUE OF ATMOSPHERIC TEMPERATURE AND WIND PROFILES.

Introduction

A catalogue of atmospheric temperature and wind profiles is being compiled using radio-sonde data to furnish the lower part of the atmospheric profile and rocket-sonde data to furnish the upper part of the profile. For a given rocket station, the nearest radio-sonde station is chosen (possibly the same as the station from which the rocket was launched), and if a radio-sonde ascent has been made within 12 hours of the rocket ascent, an attempt is made to derive a complete atmospheric profile from the two separate ascents. All colocated rocket and radio-sonde stations are within about 400 km of one another, most are within about 150 km.

The temperatures and winds are obtained as functions of pressure at the following pressure levels:-

1000mb, 700mb, 500mb, 400mb, 300mb, 200mb, 150mb, 100mb, 70mb, 50mb, 40mb, 30mb, 20mb, 15mb, 10mb, 7mb, 5mb, 4mb, 3mb, 2mb, 1.5mb, 1mb, 0.7mb, 0.5mb, 0.4mb, 0.3mb, 0.2mb, 0.15mb, 0.1mb, 0.07mb and 0.05mb.

The catalogue begins on 4 February 1976.

This catalogue has been compiled for several different purposes. Firstly it can be used to monitor the performance of satellite borne radiometers. This will be especially important for Tiros N where ultimately it is intended that two instruments borne on two separate satellites will be operated simultaneously.

Secondly, the profiles themselves will be useful for the building up of atmospheric statistics for the stratosphere. They can also be used to derive "Simulated radiances" to use in the comparison of different temperature retrieval techniques.

Wind profiles have been included as a useful check on the consistency of the temperature profiles.

Method of Processing the Radiosonde Ascent

Ascents from a list of the radio-sonde stations which are nearest to the rocket stations are extracted from the current data section of the synoptic data bank. Heights, temperatures, wind speeds and wind directions are obtained for 1000mb, 700mb 500mb, 400mb, 300mb, 200mb, 150mb, 100mb, 70mb, 50mb, 30mb, 20mb and 10mb. (Note that reports are not obtained for 40mb and 15mb which appear in the list of standard pressures for the complete atmospheric profile). The ascents are extracted from the current data bank and are transferred to a data set along with an identifying indicator for use at some later date. This is because the teletype rocket messages may not be received at Bracknell until long after the radio-sonde ascent has been removed from the current section of the synoptic data bank, and extraction from the archival section of the data bank is much more expensive in computer time and also more complicated.

The radio-sonde data have two different uses. Firstly the wind and temperature profiles are used to provide the lower part of the atmospheric profile, and secondly the height and temperature measured at a given pressure level (here 50mb) must be used to "tie" the bottom of the rocket profile since most rocket messages comprise winds and temperatures as a function of height and not of pressure as required for the purposes of radiometer/rocket-sonde comparisons.

As a result of the two above requirements, only certain radio-sonde profiles can be considered suitable for the construction of complete profiles. These are those ascents in which neither the 50mb height or pressure is flagged as missing, and those ascents in which temperature data is not missing at two consecutive pressure levels below 50mb. It was thought that ascents which did not satisfy the second requirement would not contain sufficient information at lower levels.

Any pressure levels which had missing temperatures between 1000 mb and 50mb had an interpolated temperature inserted where the temperature was determined as follows:-

$$T_m = T_{m-1} + (T_{m+1} - T_{m-1}) \frac{\ln(P_m/P_{m-1})}{\ln(P_{m+1}/P_{m-1})}$$ where m refers to the pressure

level and T and P are the temperature and pressure respectively. Because of the second requirement outlined previously, T_{m-1} and T_{m+1} always exist if T_m is missing in the original ascent.

No other corrections were made to the radio-sonde temperatures. Missing winds were left as missing.

Method of Processing Rocket Ascent

The rocket winds and temperatures are in most cases reported as functions of height only. To convert these to functions of pressure, the winds and temperatures are first of all interpolated to each kilometer level as required. (Rockets report at least once every 5 km).

The temperatures are interpolated linearly with height as follows:-

$$T_i = T_j + (T_{j+1} - T_j)\left(\frac{h_i - h_j}{h_{j+1} - h_j}\right)$$ where h is the height and

where i refers to each kilometer level and j refers to the height of the reported data. $j < i < j+1$

The wind speeds and directions are resolved to give N-S and E-W components and the components are separately interpolated as above, and then the interpolated components are recombined to give total wind speeds and directions.

As the temperatures and winds are derived as a function of height (specifically at each kilometer level), some extra information is required to convert them into functions of pressure. This extra information is the so-called "tie-on" data, and these data are obtained from the 50mb height and temperature measurements made by the colocated radio-sonde.

First the pressure and density are calculated at each kilometer level using:-

$$P_i = P_{i-1} \exp\left\{ - \frac{g(1-2h_{i-1}/r)(h_i - h_{i-1})}{R.\frac{1}{2}(T_{i-1} + T_i)} \right\}$$

and

$$\rho_i = P_i/_{RT_1}$$

where P is the pressure, T the temperature and h the height. g and r are the local acceleration of gravity and the local earth radius respectively (calculated by assuming the earth to be an oblate spheroid) and R is the gas constant.

Note that P_o = 50mb, H_o is the height of the 50mb surface as measured by the radio-sonde and T_o is the temperature of the 50mb surface as measured by the radio-sonde.

Next the winds and temperatures at given pressures can be derived since we now know the pressure of each kilometer level for which we have wind and temperature data. If m refers to the standard pressure levels and i refers to the kilometer levels, the derivation is as follows:-

$$T_m = T_i + (T_{i+1} - T_i)\left(\frac{h_m - h_i}{h_{i+1} - h_i}\right) \quad \text{where}$$

$$h_m = h_i + \frac{{}^R/2\,(T_i + T_{i+1})}{g\,(1 - h_i/r)} \ln\left(\frac{P_i}{P_m}\right)$$

Again the winds can be resolved into components and the components interpolated as above.

The standard pressure levels used in this calculation are 50mb, 30mb, 20mb, 10mb, 7mb, 5mb, 4mb, 3mb, 2mb, 1.5mb, 1mb, 0.7mb, 0.5mb, 0.4mb, 0.3mb 0.2mb, 0.15mb, 0.1mb, 0.07mb and 0.05mb (Again 40mb and 15mb are omitted), and the winds and temperatures are derived for all of the above standard pressures for which $h_{min} \leqslant h_m \leqslant h_{max}$ where h_{min} and h_{max} are the minimum and maximum heights in the original rocket report (these may be different for winds and temperatures), and h_m is the height of the

.standard pressure level.

The Processing of the Two Ascents

We now have two separate ascents which we wish to combine into one complete atmospheric profile. The ascents may or may not overlap at some of the levels between 50mb and 10mb. If the ascents do not overlap then those pairs of ascents for which the bottom of the rocket temperature profile and the top of the radio-sonde temperature profile are not at adjacent levels are considered unsuitable for further processing and are discarded. Where the top of the radio-sonde temperature profile and the bottom of the rocket temperature profile are at adjacent levels, then the complete atmospheric profile is derived from the two separate temperature profiles without further processing.

Where there is some degree of overlap between the two temperature profiles, then the two profiles are combined in such a way that the derived temperatures resemble closely the radio-sonde temperatures near 50mb and resemble closely the rocket temperatures near 10mb.

This is achieved as follows:-

$$T_m = T_m' + (T_m'' - T_m') \frac{\ln(P_m/P_1)}{\ln(P_2/P_1)} \qquad \text{where}$$

T_m' is the radio-sonde measured temperature and T_m'' is the rocket measured temperature at pressure level m, and P_1 = 70mb and P_2 = 7 mb.

This means that we now have a complete atmospheric profile of temperature except at 40 mb and 15 mb where there is no radio-sonde data and where rocket temperatures are not derived. Temperatures at these levels are derived as follows:-

$$T_{40} = T_{50} + (T_{30} - T_{50}) \frac{\ln(40/50)}{\ln(30/50)}$$

and

$$T_{15} = T_{20} + (T_{10} - T_{20}) \frac{\ln(15/20)}{\ln(10/20)}$$

where T_{50}, T_{30}, T_{20} and T_{10} have already been derived.

We now have a complete atmospheric temperature profile (with the possible exception of 1000 mb) up to pressure level m where m is at the pressure level such that h_m is the maximum height such that $h_m \leqslant h_{max}$ where h_{max} is the largest reported rocket height. If m is at a level lower than 0.7 mb, the profile is rejected as being insufficiently detailed.

No interpolation is undertaken on radio-sonde winds, and no attempt is made to interpolate between the two wind profiles. The total wind profile is obtained by supplementing the rocket winds at each pressure level with any radio-sonde winds below the bottom of the rocket wind profile.

Some Other Considerations

Most rocket stations correct the rocket temperatures for dynamic and radiative heating, and, especially at high altitudes, these corrections may be large. Occasionally, however, the rocket temperatures received are uncorrected. When this occurs the programme applies an average correction to the original rocket data to remove these effects. These corrections are made to the data before interpolation to kilometer levels is carried out. The corrections assume an average descent velocity which determines the dynamic heating correction, and during daylight an average radiative correction is applied. To determine the appropriate correction, the solar elevation angle α is calculated and if $\alpha > 0$ the day-time correction is applied and if $\alpha \leqslant 0$ the nighttime correction is applied. Strictly these corrections apply only to American rocket sondes, however, it is probable that by applying the corrections to other rockets, a vast improvement would be obtained compared with the uncorrected data.

Organisation of Data

The catalogue has been created on magnetic tape, and contains the following information:-

1) Temperatures for all standard pressure levels in degrees C. All missing temperatures are flagged with - 3276.8.

2) Wind speeds and directions in knots and degrees respectively at each standard level. Again missing data are flagged.

3) The rocket station index

4) The time of the rocket ascent relative to the radio-sonde ascent (hours)

5) The day, month and year of the radio-sonde ascent

6) The hour of the radio-sonde ascent

7) The temperature correction code for the raw rocket data. A correction code of zero denotes that the original data are uncorrected, however the programme applies an average correction as explained in the previous section. Codes 1, 2, 3 and 4 are for American, British, Japanese and Russian correction methods respectively.

8) The latitude and longitude of the rocket station. (degrees and tenths $-180 \leqslant \phi \leqslant 180$).

9) The local acceleration of gravity and the local earth radius at the rocket station (Cm/sec^2 and hm).

10) The radiosonde station index.

11. The radio-sonde sonde type code (as used in the SIRS/sonde colocation programme).

12) The latitude and longitude of the radio-sonde station. (degrees and tenths $-180 \leqslant \phi \leqslant 180$).

13) The "tie-on" data consisting of the base height, temperature and pressure obtained from the radio-sonde profile to "fix" the bottom of the rocket profile. (geopotential kilometers, degrees C and mb respectively).

14) The solar elevation angle in degrees, where the time used to derive is as reported in the rocket message. No allowance is made for any time lag in reaching a given pressure level, or the difference in altitude between different pressure levels.

15) An undefined parameter for possible later use is also stored.

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